Chapter 7
Spills

Introduction

As part of the initial activities to define the scope of this report, a workshop was held to identify the state of understanding of the environmental aspects of Orimulsion use, including its behavior and effects when spilled into water (EPA 1999a). The workshop noted that there was "an extensive body of published information on spills," although most of it was based on research sponsored by Bitor. The workshop concluded that very little information was available concerning the behavior and effects of an Orimulsion spill in fresh water, but that the primary responsibility for conducting the research necessary to supporting any application required for using Orimulsion in the U.S. rested with Bitor. The recommendations of the workshop were that if Bitor does begin to develop U.S. customers at sites accessible only by fresh water, at a site near bodies of fresh water, or at a site where fresh water can be contaminated by a spill, even indirectly, Bitor should be responsible for the research to address the data gaps as they have done for marine environments. Such research does not fall under the Congressional directive for this report, and should not be considered to be EPA's responsibility under that directive. However, since EPA is responsible for responding to spills in certain situations, the Agency should continue to investigate Orimulsion spill behavior and response as appropriate. EPA (in collaboration with the U.S. Coast Guard) has requested the National Academy of Sciences to conduct a study on Orimulsion to evaluate what additional information is required to effectively respond to freshwater spills. EPA is currently conducting smaller studies on spill behavior modeling, and will address the data gaps identified by the NAS as appropriate. For these reasons, the Orimulsion Technology Assessment Plan did not include research into the behavior and effects of Orimulsion spills into fresh water.

Background

Spills are of concern when transporting any liquid material by ship, barge, or pipeline, when leakage or accident has the potential to introduce the liquid into bodies of water near the site of material transfer or use, or when the liquid contaminates runoff or enters other indirect routes to bodies of water. Concerns about spills can be divided into two main areas: (1) spill response and cleanup; and (2) impact of the spilled material on the environment. Orimulsion has two properties that distinguish it from many other fuels from the perspective of spills. The first property that is of concern is that the bitumen portion of Orimulsion is heavier than fresh water at ambient temperatures (see Chapter 2 for discussion of Orimulsion's properties). The second property is the presence of a surfactant in the fuel, which acts to prevent the bitumen from coalescing into larger particles or spills that can be more easily collected.

The bitumen in Orimulsion has a density greater than that of fresh water (see Table 2-1). This means that Orimulsion is considered to be a "Group V oil" as defined by the U.S. Coast Guard (Federal Register 1996). Group V oils are those that have specific gravities greater than 1.0, and generally do not float on water. A committee of the National Research Council (NRC), the Committee on Marine Transportation of Heavy Oils, recently evaluated the risks of nonfloating oil spills and methods of responding to those spills (National Research Council 1999). This study included an evaluation of emulsified oils and of Orimulsion as a special case of heavy emulsified fuels.

The term *heavy oil* in the NRC report was used to describe dense, viscous oils with low volatility (flash point higher than 65 °C), very little loss by evaporation, and viscous to semisolid consistency. The report gave examples of heavy oils as including Venezuela, San Joaquin, and Bunker crude oils, residual oils (Nos. 5 and 6 fuel oil, Bunker C, and slurry oil), asphalt, coal tar, coke, carbon black, and pitch. *Nonfloating oils* is the term used by the NRC Committee to describe oils, like some heavy oils, that do not float on water. This includes oils that sink immediately, those that mix into the water column and move with the water in suspension, and those that have a portion of the fuel that initially floats, but mixes with sand or sediment and then sinks.

To date, there have been no significant spills of Orimulsion. One could estimate the probability of an

Orimulsion spill during transport based on the reported frequency of transport-related heavy oil spills; however, Bitor's policy to date has been to use double-hulled vessels for transport, which reduces spill potential. Additionally, Orimulsion has not been transported by barge, which accounts for the bulk of spill volume. The NRC study reported that the average annual movements of heavy oils were 45.7x10^9 ton-miles per year in the period 1991 through 1996. During the same time period, the annual volume of heavy oil spills was 10,840 bbl/year, resulting in a spill ratio of 237 bbl spilled per 10^9 ton-miles. Of the total, barge transport accounted for 19.6x10^9 ton-miles per year, 9,765 bbl/year spilled, and a spill ratio of 499 bbl spilled per 10^9 ton-miles (see Figure 7-1). Nonfloating oils were estimated to account for approximately 20% of the total heavy oil volume (National Research Council 1999). The spills per 10^9 ton-miles rates are likely to be higher for

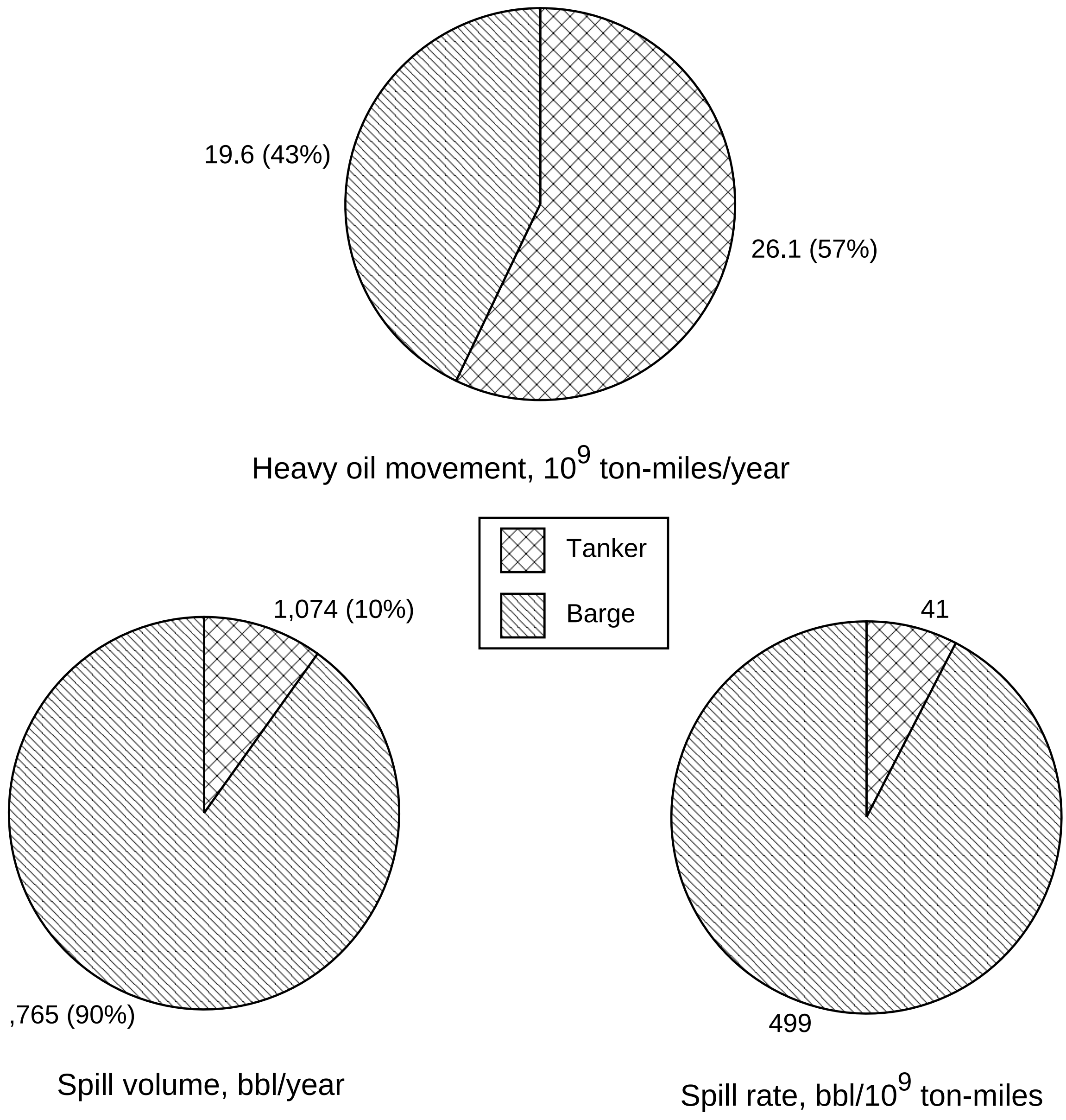

Figure 7-1. Movement, spill volumes, and spill rates of heavy oils in U.S. domestic waters between 1991 and 1996 (data from National Research Council 1999).

heavy oils than for Orimulsion due to the reliance on tankers versus barges, and the use of double-hulled versus single-hulled tankers.

It should be noted that more spills occur at stationary facilities than during transport. These spills can enter bodies of water through containment leakage, storm drains, sewers, or other indirect routes. Such spills can also pose a greater threat to public drinking water supplies, since the facilities are often located closer to populated areas and therefore nearer to water supply inlets.

The study found that nonfloating oils behave differently and have different environmental fates and effects than floating oils. In contrast to floating oils, nonfloating oils when spilled can pose "a substantial threat to water-column and benthic [sea, river, or lake bottom] resources, particularly where significant amounts of oil have accumulated on the seafloor" (National Research Council 1999). Such spills do not quickly degrade, and can impact resources for a longer period of time than do floating spills, although the effects and behavior of such spills are poorly understood. Spills of nonfloating oils are difficult to track, since the spill plume is largely underwater. While a number of tools and techniques have been developed for tracking such spills, the actual performance of these tools is unknown either through controlled experiments or application to spills. In addition, there are few technologies available for effectively containing and recovering spilled nonfloating oils. Those methods that are currently used are often effective only in areas with very low currents and minimal wave activity. Once the oil has deposited on the sea or river bed, recovery of the spilled oil can be done manually by divers (a slow and labor intensive method) or by dredging. However, dredging tends to collect substantial amounts of other sediments and materials, and proper disposal of the collected materials can be problematic (National Research Council 1999).

The surfactants present in emulsified fuels will maintain their effectiveness in fresh water longer than in salt water. Figure 7-2 shows the behavior of emulsified fuels in spills for low- and high-current fresh water and for high currents in salt water. In low-current conditions in fresh water, the spilled fuel will settle to the bottom of the water column, with low potential for mixing with bottom sediments in the short term (National Research Council 1999).

In fresh water with high currents, the bitumen particles will settle toward the bottom down-current of the spill (see Figure 7-3). The surfactant will remain effective for a limited period of time, preventing

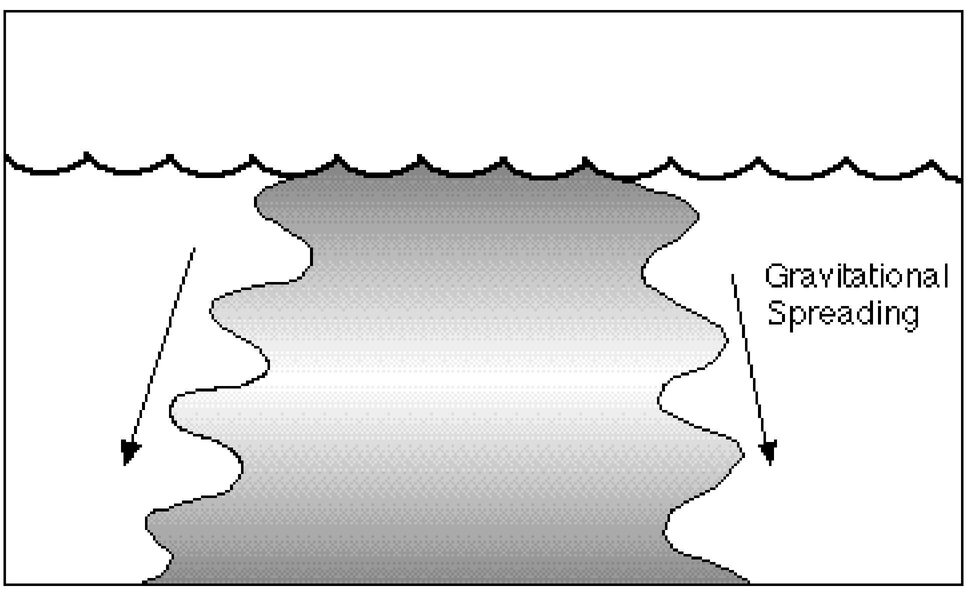

Figure 7-2. Spill of nonfloating oil in low-current fresh water (adapted from National Research Council 1999).

recoalescence of the fuel particles. The deposition rate of the particles may increase if the bitumen particles (which are highly adhesive) interact with fine-grain sediments, increasing the particles' density. In addition, many freshwater riverine systems are high in suspended solids to which the bitumen is likely to adhere. Usually, the suspended materials occur close to the bottom as a "floc." This floc once mixed with bitumen will be changed in physical/chemical character. These materials are deposited in the more quiescent submerged regions of a river.

In saltwater spills, emulsified oils will form clouds of dispersed particles in the upper 1-2 meters of the water column, as shown in Figure 7-4. In such instances, the surfactants lose their effectiveness more quickly than in fresh water, allowing the bitumen particles to coalesce and rise to the surface, forming tarry slicks. In open water, the particles are likely to disperse, resulting in increased difficulty in containing and recovering emulsified fuels as the time from the spill increases (National Research Council 1999).

Bitumen particles pose a threat in more ways than just "smothering." Many freshwater benthic inhabitants are at risk by being exposed to the fine particles of bitumen during feeding and tube building activities. Some benthic invertebrates produce membranous nets that capture the fine detrital materials that are passing by in the current. Bitumen, even dispersed bitumen, is likely to be entrapped and consumed by this type of feeding.

Reported Orimulsion Spill Studies

The NRC report cited four studies on Orimulsion spill behavior which were used to form the basis of the NRC report. These studies were largely funded by Bitor or other interested parties. The U.S. Coast Guard recently published a report (conducted by Battelle and funded by the U.S. Coast Guard Research and Development Center, and Bitor) on the behavior of Orimulsion spills (Battelle 1999). This report cites a number of studies that have been done on characterizing Orimulsion behavior in spill situations. There have also been two recent documents prepared by Environment Canada regarding Orimulsion spills in marine environments. One is a spill field guide, and the other discusses options for disposing of bitumen recovered from a spill (Owens and Sergy 1999, Guénette and Sergy 1999). The reports cited by the NRC, the U.S. Coast Guard, and Environment Canada that are specific to Orimulsion behavior are listed in Appendix F.

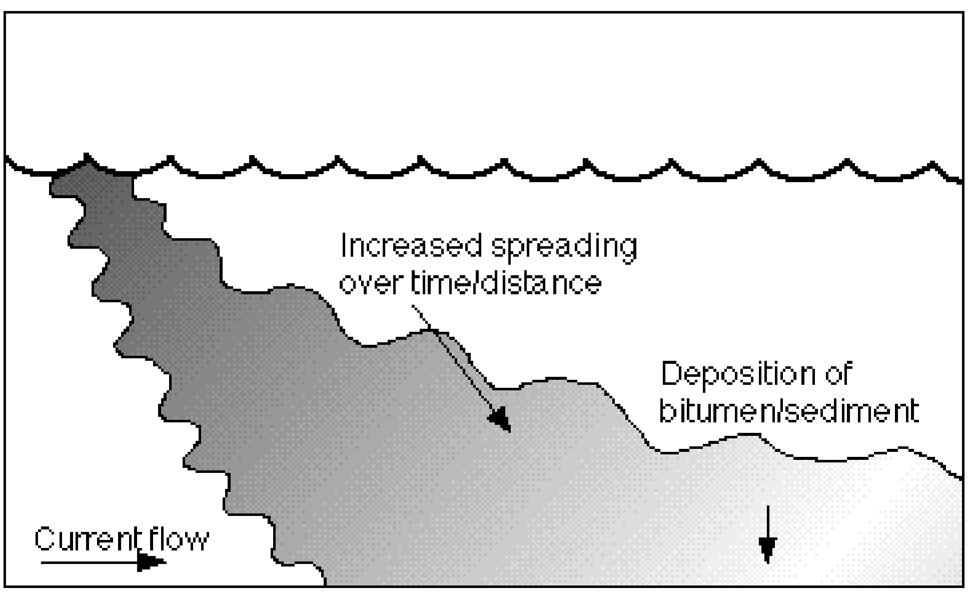

Figure 7-3. Spill of nonfloating oil in high-current fresh water (adapted from National Research Council 1999).

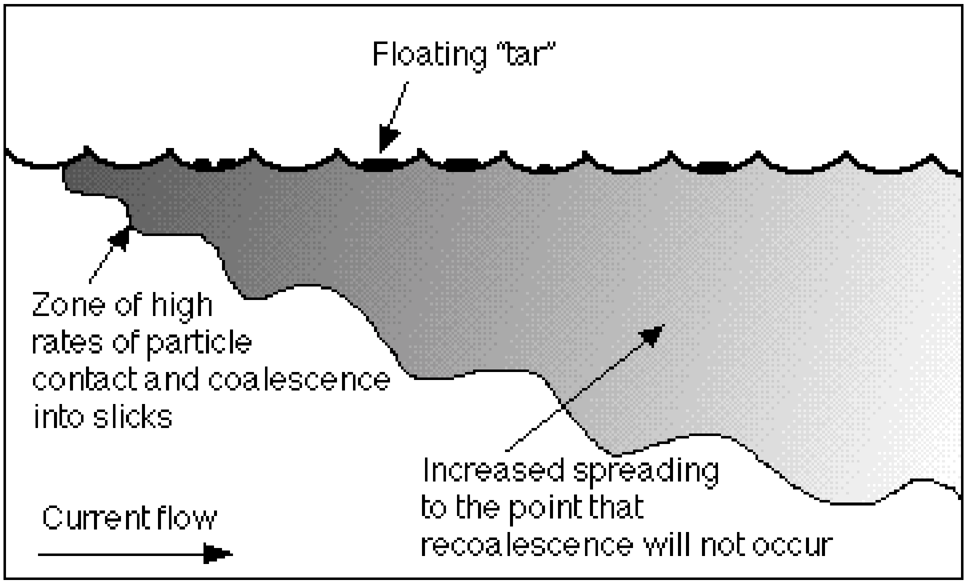

Figure 7-4. Spill of nonfloating oil in high-current salt water (adapted from National Research Council 1999).

Saltwater Spills

A number of studies of Orimulsion spills have been conducted, including containment and recovery and fate and effects studies. Most, if not all, of these studies have been funded by Bitor, and have been conducted by a range of organizations, including the University of Massachusetts, the University of Miami, Environment Canada, and the U.S. Coast Guard. To date, nearly all of this work has focused on marine (saltwater) spills. Research in the area of Orimulsion spills has largely been guided over the past several years by the International Orimulsion Working Group (IOWG). The IOWG includes members from Bitor, the U.S. Coast Guard, the Canadian Coast Guard, and Environment Canada.* These studies include investigations of spill behavior, identification of spill plume tracking technologies, evaluation of spill containment and recovery equipment and techniques, and toxicological studies of the impact to marine life of exposure to Orimulsion.

Bitor has developed methods for spill containment and recovery (Bitor America 1999), and has conducted limited open water testing of these techniques. No "real-world" test of the methods has been conducted, as there have been no spills of Orimulsion reported to date.

Special spill containment equipment designed to handle Orimulsion is on site at terminals in Canada and Denmark (Irvine and Eagles 1998, Miller and Shores 1999), as well as at other sites where Orimulsion is off-loaded.

Freshwater Spills

There is little technical information available on what happens when Orimulsion is spilled into fresh water. As noted above, Orimulsion is a heavy oil, meaning that it has high specific gravity and is likely to sink once spilled into fresh water.

Contamination of fresh water can occur during activities other than transport. Storage and handling activities at sites near bodies of fresh water such as lakes, ponds, or rivers have the potential to release

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*In the U.S., the responsibility for responding to oil spills in marine environments generally rests with the U.S. Coast Guard, with spills occurring in freshwater environments generally being the responsibility of the U.S. EPA. EPA has not participated in the IOWG.

a fuel into those bodies. Even in instances where a spill occurs at a site not located immediately next to a body of fresh water, storm drains or other means can result in indirect contamination.

Laboratory tests in fresh water conducted by Environment Canada and Battelle indicate that the bitumen particles in Orimulsion accumulate on the bottom of the test vessels with very little material remaining on the surface.

The ramifications of this behavior are many:

(a) If Orimulsion behaves in a freshwater body as it does in the laboratory, then the bitumen particles can sink through the water column and be deposited on the bottom, downstream from the spill location. Orimulsion is not a liquid but a heavier-than-water suspension which dissipates once spilled. The impact from this behavior would likely be the smothering of benthic organisms living on or in the sediments. The Battelle study indicated that the bitumen fraction of Orimulsion would sink to the bottom under calm water situations, and that in low energy situations, dilute Orimulsion remained in suspension. The new data suggest that pelagic (open-sea) species may also be vulnerable if low energy levels keep Orimulsion in suspension (Battelle 1999).

(b) Oil spill cleanup technology is based upon removing the spilled product from the water surface and contaminated surfaces. Subsurface removal of a sunken product is limited to accumulations in distinct pockets, indentations, or depressions. The lighter-than-water spilled product sometimes is entrained and adheres to bottom substrates, e.g., cobble, algae and aquatic vegetation. This product will often float to the surface if disrupted and dislodged where conventional equipment can remove the product from the surface. Orimulsion does not have the same physical properties and will not resurface in fresh water.

    Castle et al. (1995) characterized fate and transport mechanisms and removal techniques for sunken oils. The assessment procedures mentioned in their paper are more applicable for marine waters but have some application for the freshwater environment. They stressed the importance of field observations made from aircraft and predictive models to ascertain the probable fate and transport of a spill of heavier-than-water petroleum product. Accessing expertise in local resource and navigation offices can be helpful in determining sinks and collection spots on the bottom of a receiving water body. An assortment of geophysical instruments and techniques have been shown to be valuable in locating and mapping submerged product.

    Physical removal of bitumen is currently limited to a subsurface operation using divers and vacuum hoses. Limited success for containing bitumen using fish netting was observed in tests performed in a wave tank in Canada (Brown and Goodman 1989). In these tests, bitumen leaked through the netting being towed at 0.3 m/s (0.77 miles/hour), indicating that in currents carrying spilled bitumen at greater than 0.3 m/s, bitumen would not be completely trapped and contained. A spill of fresh Orimulsion would even be harder to trap and contain due to the smaller particle size of the bitumen/surfactant.

    Many conventional oil booms will begin to leak under the boom (i.e., entrain) at about 0.75 knot. In higher currents, the booms can be placed at an angle to the current (i.e., deflection booming) so that the normal current to the boom is below 0.75 knot. This prevents the boom from leaking and allows the operator to divert the oil to a quieter area where it can be removed from the surface with conventional skimming equipment. These techniques may possibly be employed with an Orimulsion spill by deploying booms below the surface to collect and then recover the bitumen using vacuum pumps. However, no tests of this approach have been documented.

    Several technologies for recovery of Orimulsion and Orimulsion bitumen in fresh- and saltwater environments are in various stages of development (Bitor America 1997, 1999;

Lorenzo 1996). However, one of the areas of concern for these experimental recovery systems is their "scalability." As the Orimulsion becomes more dispersed, more water must be pumped through the system with the Orimulsion. While these approaches may be reasonably effective in the lab, the question remains as to how effective they will be when pumping large quantities of water through them in an actual spill. Further, none of these techniques have been demonstrated in riverine environments, which require different approaches and in some cases different technologies compared to open water spill recovery methods.

The lack of case histories of Orimulsion spilled into fresh water leaves speculation and assumptions as to the fate and transport of this product. Considering the state of the knowledge and practices for oil spill cleanup, which is geared primarily toward removing surface oil, the degree of success for removing subsurface deposits of spilled Orimulsion remains an open question. In the absence of more information, a conservative assumption is that an Orimulsion spill will defy cleanup by conventional means and the material will therefore remain intact in the environment.

(c) Orimulsion is composed mostly of bitumen, which is a complex mixture of hydrocarbons and is similar in handling and content to liquefied asphalt (Deis et al., 1997). Some of the hydrocarbon compounds associated with this fraction are known carcinogens; e.g., benzopyrenes (Jokuty 1999). One of the dangers of a spill of Orimulsion into a major freshwater body would be the threat presented to public water supplies. Most public water supply intakes are submerged. A submerged plume of spilled Orimulsion moving downstream could intercept an intake pipe and be drawn into the supply, especially if the plant operators had not been warned beforehand to cease pumping. A slug of Orimulsion could potentially overwhelm a water supply treatment capacity for removing organics including some of the carcinogenic compounds mentioned above. Most plants are set up to remove settlable solids and low concentrations of organics but not heavier-than-water liquids or suspensions; e.g., heavy oils, Orimulsion.

Data Gaps

As the above sections show, a number of data gaps exist with respect to understanding the behavior and fate of Orimulsion spilled in fresh water. Because of the significant increase in cost associated with transfer of the fuel from ocean-going tankers to barges or other means of transport, Bitor's current plans are to develop U.S. customers only at sites accessible by ocean-going tankers. Nevertheless, understanding the behavior and fate or Orimulsion in fresh water is important due to the presence of streams, wetlands, and other bodies of fresh water near a site that receives Orimulsion by ocean, and because of the potential for Orimulsion to enter bodies of fresh water through indirect routes such as storm drains. Any freshwater bodies near a site using Orimulsion may be impacted by a spill that occurs during fuel handling or other activities not associated with marine shipment.

As noted in the Orimulsion Technology Assessment Plan (EPA 1999a), if Bitor does begin to develop U.S. customers at sites accessible only by fresh water, at a site near bodies of fresh water, or at sites where freshwater contamination may occur (even if indirectly), Bitor should fund the research to address the data gaps as they have done for marine environments. Such research does not fall under the Congressional directive for this report, and should not be considered to be EPA's responsibility under that directive. However, since EPA is responsible for responding to spills in certain situations, the Agency should continue to investigate Orimulsion spill behavior and response as appropriate.

EPA and the Coast Guard have initiated a study on Orimulsion by the National Academy of Sciences to evaluate the information needed to develop an effective Orimulsion spill response. EPA will use this guidance to determine what additional research may be required to support their regulatory requirements with regard to spill response. Other work on Orimulsion is being carried out within EPA's Office of Research and Development to more fully characterize specific chemical and physical properties of Orimulsion and to evaluate a spill behavior model and extend the model to cover Orimulsion.